3.0 Land Use Assessment

A description of general types of land use activities crossed by Corridors 3A, 3B, 5A, and 5C is presented, as well as a discussion of major jurisdictional land use issues that exist for each corridor. Corridors 3A, 3B, 5A, and 5C begin at Drop No. 1 on the All-American Canal (AAC). However, extending these corridors eastward along the AAC to the Colorado River at Imperial Dam is also considered. Therefore, the discussion in this section includes land use issues identified from Imperial Dam to either San Vicente Reservoir or the second San Diego aqueduct. The term "Parallel Canal Corridor" is used in this section to refer to that portion of each corridor constructed as canal and aligned parallel to the AAC, Westside Main Canal, Thistle Canal, and the Trifolium Extension.

Land use issues for the Beeler Canyon Tunnel are addressed in the Draft EIR/EIS for the Emergency Storage Project. Land use issues associated with Corridor 1A have not been evaluated at this time.

Three separate mileposting sequences are utilized to reference locations along the alternate corridors. The initial starting point for mileposting the corridors was at the terminus of the AAC for Corridor 5C, at the Westside Main Canal near Dixieland for Corridor 5A, and at a point along the Thistle Canal approximately 5 miles north of its intersection with the Westside Main Canal for Corridors 3A and 3B. For each of these four corridors, the mileposting starts at 0 on the east and increases to the west into San Diego County to the terminus of the corridor at either San Vicente Reservoir or the Twin Oaks Diversion Structure. This is the milepost sequence which is shown on the Land Use Map (Plate 3-1), Geologic Maps (Plates 4-1 and 4-2), and Environmental Map (Plate 10-1).

A separate milepost sequence was established for a portion of the Parallel Canal Corridor beginning with milepost (MP) 0 at Drop 1 on the AAC and increasing to the west. This sequence encompasses the portion of each corridor aligned parallel to the AAC (west of Drop 1), Westside Main Canal, Thistle Canal, and Trifolium Extension.

To accommodate the consideration of a canal extension parallel to the AAC back to the Colorado River at Imperial Dam, a third mileposting sequence was established with MP 0 at Imperial Dam increasing to the west to Drop 1.

Table 3-1 provides a summary of jurisdictional land uses crossed by or adjacent to a canal aligned parallel to the ACC, Westside Main Canal, and Thistle Canal (Parallel Canal Corridor).

Table 3-1
Jurisdictional Land Uses for the Parallel Canal Corridor

Segment	Milepost	Jurisdictional Land Use	Parallel To
Imperial Dam to Drop 1	0 - 3.8	BLM Land	AAC
	3.8 - 21.2	Fort Yuma Indian Reservation	AAC
	21.2 - 24.6	BLM Land	AAC
	24.6 - 35.0	BLM Imperial Sand Dunes Recreation Lands	AAC
Drop 1 to Thistle Lateral	0 - 20.8	BLM Land	AAC
	20.8 - 25.6	Private	AAC
	25.6 - 26.1	Agricultural Land	AAC
	26.1 - 44.3	Private	AAC
	44.3 - 45.8	Private	Westside Main Canal
	45.8 - 46.2	BLM Land	Westside Main Canal
	46.2 - 51.5	Private	Westside Main Canal
	51.5 - 51.9	BLM Land	Westside Main Canal
	51.9 - 52.3	Private	Westside Main Canal
	52.3 - 52.8	BLM Land	Westside Main Canal
	52.8 - 53.2	Private	Westside Main Canal
	53.2 - 53.4	BLM Land	Westside Main Canal
	53.4 - 59.7	Private	Westside Main Canal
	59.7 - 60.2	BLM Land	Westside Main Canal
	60.2 - 68.6	Private	Westside Main Canal
	68.6 - 70.5	BLM Land	Westside Main Canal
	70.5 - 75.9	Private	Thistle Canal

Table 3-2 provides a summary of jurisdictional land uses crossed by or adjacent to the alternate routes located west of the Westside Main Canal. The alternate routes are shown on the land use map, Plate 3-1, which is provided at the end of this section.

3.1 Parallel Canal Corridor

3.1.1 General Land Use Description

The Parallel Canal Corridor begins immediately south of the desilting tanks at Imperial Dam along the Colorado River. From its beginning point to Drop 1, the Parallel Canal Corridor is located along the AAC. As shown in Table 3-1, the corridor crosses BLM land from MP 0 to approximately MP 3.8. At approximately MP 3.8, the corridor enters the Fort Yuma Indian Reservation and continues through the reservation until approximately MP 21.2. The Potholes Cemetery is located near MP 4.7, within the Indian Reservation. The corridor crosses Interstate 8 at approximately MP 19.3. From approximately MPs 19.3 to 24.6, the corridor crosses BLM land. From MPs 24.6 to 35.0, the corridor crosses the Imperial Sand Dunes Recreation Lands. At MP 30.1, the corridor crosses Interstate 8. From this point to approximately MP 32.2, Interstate 8 is located within 300 feet of the AAC.

From Drop 1 to the Westside Main Canal, the corridor is located on the north side of the AAC. From MPs 0 to 20.8, the corridor crosses BLM land. At approximately MP 0.6, the corridor crosses Interstate 8. From approximately MPs 20.8 to 25.6, the corridor crosses private land. The corridor crosses the Alamo River at approximately MP 25.6. From MPs 25.6 to 26.1, the corridor crosses agricultural land. From MPs 26.1 to 75.9, the route crosses private land, with the exception of scattered small areas of BLM land. At approximately MP 31.3, the corridor crosses the Central Main Canal. At MP 33.7, the corridor crosses State Route 99. At MP 36.2, the corridor crosses the New River. From MP 44.3 to where the canal becomes a pipeline, the corridor has been assumed to run on the west side of the Westside Main Canal, Thistle Canal, Thistle Lateral, Trifolium Storm Drain, and the Trifolium Extension.

3.1.2 Jurisdictional Land Use Issues

The major jurisdictional land use permitting issues associated with the Parallel Canal are as follows:

- Crossing the Fort Yuma Indian Reservation between MPs 3.8 and 21.2 east of Drop 1.
- Crossing the BLM Imperial Sand Dunes Recreation Lands between MPs 24.6 and 35.0 east of Drop 1.

Table 3-2
Jurisdictional Land Uses West of the
Westside Main Canal

Corridor	Milepost	County	Jurisdictional Land Use
3A	0-15.0	Imperial	Agriculture (Private)
	15.0-17.0		Bureau of Land Management, SR 78
	17.0-18.0		Bureau of Land Management ACEC, SR 78
	18.0-30.0		Agriculture (Private) and Bureau of Land Management, SR 78
	30.0-34.0	San Diego	Ocotillo Wells Vehicle Recreation Area, SR 78
	34.0-44.0		Anza-Borrego Desert State Park, SR 78 and S3
	44.0-51.0		Private (Borrego Springs), S3
	51-55		Anza-Borrego Desert State Park (Tunnel MP 51 - 95)
	55-56		Anza-Borrego Desert State Park Sheep Canyon Wilderness Area
	56-74		Private
	74-76		Cleveland National Forest
	76-79		Private
	79-83		Bureau of Land Management and Private
	83-95		Private
3B	0-15.0	Imperial	Agriculture (Private)
	15.0-17.0		Bureau of Land Management, SR 78
	17.0-18.0		Bureau of Land Management ACEC, SR 78
	18.0-30.0		Agriculture (Private) and Bureau of Land Management, SR 78
	30.0-35.0	San Diego	Ocotillo Wells Vehicle Recreation Area, SR 78
	35.0-48.0		Anza-Borrego Desert State Park, SR 78
	48.0-51.0		Anza-Borrego Desert State Park Wilderness Area, SR 78
	51.0-55.0		Anza-Borrego Desert State Park, SR 78 (Tunnel MP 52 - 54)
	55.0-60.0		Private, SR 78
	60.0-61.0		Bureau of Land Management (Tunnel MP 60 - 84.5)
	61.0-62.0		Private
	62.0-76.0		Cleveland National Forest
	76.0-78.0		Private
	78.0-81.0		Bureau of Land Management
	81.0-84.5		Private
5A	0-3	Imperial	Agriculture (Private), RR ROW
	3-5		Bureau of Land Management, RR ROW
	5-6		Private (Plaster City), RR ROW
	6-10		Bureau of Land Management, RR ROW
	10-12		Private (Ocotillo), RR ROW
	12-17		Private (Ocotillo)
	17-22		Bureau of Land Management

Table 3-2 (Continued)
Jurisdictional Land Uses West of the
Westside Main Canal

Corridor	Milepost	County	Jurisdictional Land Use
	22-30	San Diego	Anza-Borrego Desert State Park (S-2 Sweeny Pass Road)
	30-36		Anza-Borrego Desert State Park Wilderness Area (Tunnel MP 30 - 71.2)
	36-39		Bureau of Land Management
	39-46		Cleveland National Forest
	46-48		Private (Pine Valley)
	48-57		Cleveland National Forest
	57-64		Private (Alpine)
	64-71.2		Private
5C	0-1.0	Imperial	Agriculture (Private)
	1.0-12.0		Bureau of Land Management
	12.0-20.0		Bureau of Land Management, SR 98
	20.0-22.0		Private (Ocotillo), SR 98, Interstate 8
	22-27		Bureau of Land Management, Interstate 8
	27-28		Private, Interstate 8
	28-30		Bureau of Land Management
	30-32	San Diego	Private
	32-33		Bureau of Land Management
	33-48		Private
	48-51		Bureau of Land Management
	51-65		Private
	65-67		Bureau of Land Management
	67-72		Cleveland National Forest
	72-85		Private

3.2 Corridor 3A West of Parallel Canal Corridor

3.2.1 General Land Use Description

The first 14 miles of Corridors 3A and 3B begin as an expanded or new parallel canal starting at a point approximately 5 miles north of the intersection of the Thistle Lateral and the Westside Main Canal in Imperial County. The remainder of the corridor is either cut-and-cover pipeline or tunnel to the termination point in San Diego County. The corridor crosses privately owned agricultural land parallel to the existing Thistle Lateral to the intersection with State Route (SR) 86/78. From this point, Corridors 3A and 3B cross privately owned agricultural land along the road right-of-way (ROW) to the intersection of (SR) 86 and (SR) 78. The corridors then head west along (SR) 78. As the corridors continue along (SR) 78, they pass through a patchwork of BLM land and privately owned land.

Upon entering San Diego County, the corridors cross the Ocotillo Wells Vehicle Recreation Area before entering the Anza-Borrego Desert State Park. The corridors follow (SR) 78 within the Anza-Borrego Desert State Park, for approximately 5 miles before the point where Corridors 3A and 3B split. Corridor 3A then heads north along County Highway S-3, still within Anza-Borrego Desert State Park, before entering the Borrego Springs community, which is not a part of the Anza-Borrego Desert State Park. Before entering the town of Borrego Springs, the corridor heads west, leaving the road and crosses privately owned property. The corridor then portals into tunnel within private property and then re-enters Anza-Borrego Desert State Park. At this point, the corridor would be tunneled until it terminates at the second San Diego aqueduct. The tunnel may potentially cross beneath a portion of the Sheep Canyon Wilderness Area within the Anza-Borrego Desert State Park before exiting the park boundaries. A minor corridor realignment would avoid this wilderness area (WA).

The corridor continues west through privately owned land between two areas of the BLM San Ysidro Wilderness Study Area. The corridor continues through privately owned land, passing north of the Mesa Grande Indian Reservation and south of Lake Henshaw. The route enters the Cleveland National Forest for approximately 2 miles. The corridor then continues west, crossing BLM land and passing north of the San Pasqual Indian Reservation, through privately owned land in the community of Valley Center. A riser shaft and flow control facility would be located at a potential terminal reservoir (Moosa Reservoir). The tunnel would then continue to the Diversion Structure located east of Interstate 15 in the Twin Oaks Valley area.

3.2.2 Jurisdictional Land Use Issues

The major jurisdictional land use permitting issues associated with Corridor 3A are as follows:

- Crossing Anza-Borrego Desert State Park following (SR) 78 and other roads using trenching between Mileposts 34-44.
- Crossing Anza-Borrego Desert State Park using tunneling between Mileposts 51-52 and 54-55.
- Potentially crossing Anza-Borrego Desert State Park Sheep Canyon WA using tunneling between Mileposts 55-56.

Between Mileposts 34-44, this corridor would generally follow (SR) 78 across a portion of Anza-Borrego Desert State Park using trenched construction. The corridor would probably be located outside of the actual (SR) 78 ROW and would, thus, cross the State Park immediately adjacent to the highway.

Preliminary communications with Mr. Dave van Cleeve, District Superintendent of the California Department of Parks and Recreation, indicate that this corridor could probably be permitted, under the following general conditions:

- (SR) 78 was closely paralleled
- Important public use areas were avoided.
- Surface disturbance was minimized and all adverse impacts were mitigated.
- No portals or tunnel spoil areas would be permitted within the State Park.
- Sensitive environmental resources were avoided.

In general, Mr. van Cleeve expressed a strong interest in avoiding crossing of Anza-Borrego Desert State Park if other alternative corridors could be used. However, he also indicated that a corridor across the State Park could probably be permitted if their mitigation requirements were met. We believe that, at least, some of their mitigations would probably be significant in terms of costs and other factors.

Traffic is not expected to be an issue associated with the trenching of the corridor along (SR) 78. The corridor will be paralleling the existing Caltrans ROW and will actually be located outside of the Caltrans ROW.

There probably will not be any significant jurisdictional land use permitting issues associated with tunneling under Anza-Borrego Desert State Park outside of WAs.

Preliminary communications with Mr. Dave van Cleeve indicate that the California Department of Parks and Recreation is concerned about potential adverse effects on State WA values. Mr. van Cleeve strongly indicated that surface disturbances related to construction or operation (such as routine or emergency repairs) would not be permitted in a State WA. We believe that it would probably not be possible to construct an exploratory drill site, shaft, portal, access road or any other surface facility in a State WA. Mr. van Cleeve further indicated that it might be possible to permit tunnel construction under a State WA as long as wilderness values were not adversely affected by project construction or operation. This issue needs to be further discussed with the Department of Parks and Recreation to complete project definition.

3.3 Corridor 3B West of Parallel Canal Corridor

3.3.1 General Land Use Description

Corridor 3B, continuing from the point where it splits with Corridor 3A, passes through Anza-Borrego Desert State Park along (SR) 78. This section is all pipeline except for a tunnel section southeast of Sentenac Canyon where San Felipe Creek has cut a narrow gorge. From the west portal of this tunnel, the corridor continues southwest along (SR) 78 as pipeline to the community of Banner where it becomes tunnel again and then enters the Cleveland National Forest. The corridor remains in tunnel as it passes through BLM and private land and heads west to San Vicente Reservoir, entirely in tunnel

3.3.2 Jurisdictional Land Use Issues

The major jurisdictional land use permitting issues associated with Corridor 3B are as follows:

- Crossing Anza-Borrego Desert State Park along (SR) 78 using trenching between Mileposts 35-48, and using a combination of trenching and tunneling between Mileposts 51-55.
- Crossing Anza-Borrego Desert State Park WAs along (SR) 78 between Mileposts 48-51 using trenching.
- Having two tunnel portals for the tunnel parallel to Sentenac Canyon in Anza-Borrego Desert State Park.

Between Mileposts 35-48, this corridor would generally follow (SR) 78 across a portion of Anza-Borrego Desert State Park using trenched construction. The corridor would probably be located outside of the actual (SR) 78 ROW and would, thus, cross the State Park immediately adjacent to the highway. The issues and conditions associated with following (SR) 78 and other roads using trenching are the same as addressed for Corridor 3A.

The same requirements would apply to the section of the corridor located between Mileposts 51-55 which would be constructed using a combination of trenching and tunneling. It should be noted that two tunnel portals would be required for the tunnel parallel to Sentenac Canyon. This is necessary in order to avoid trench construction in Sentenac Canyon.

Between Mileposts 48-51, this corridor would follow (SR) 78 using trenching between two WAs located in the State Park. The corridor in this area would be located directly adjacent to or in the floodplain of San Felipe Creek, directly adjacent to the highway ROW. Locating the corridor within the San Felipe Creek floodplain in this area is proposed due to the presence of steep rocky terrain on the other side of (SR) 78. Determining the specific boundaries of the two WAs on either side of the corridor in this area will be very important. Mr. van Cleeve indicated that, in general, crossing of a State WA using trenched construction on the surface would not be permitted. In this area, we believe that it will probably be necessary to avoid crossing of the two WAs using trenched construction.

3.4 Corridor 5A West of Parallel Canal Corridor

3.4.1 General Land Use Description

Corridor 5A begins as pipeline at the Westside Main Canal at Dixieland and heads west along an existing railroad ROW. Land on either side of the ROW is privately owned for a short distance, becoming BLM land up to the intersection of the railroad ROW and Interstate 8. At this point, the corridor enters the community of Ocotillo and crosses private land. After exiting the Ocotillo community, the corridor enters BLM land designated as the Yuha Desert Recreation Area. The corridor continues northwest and enters the Anza-Borrego Desert State Park at the San Diego County line. At Milepost 30, the corridor becomes tunnel. The corridor remains in tunnel all the way to El Capitan Reservoir.

At the portal at Milepost 30, the route enters an Anza-Borrego Desert State Park WA, continuing southwest, crossing BLM land before entering the Cleveland National Forest. The corridor then crosses private land in the Pine Valley community. The route continues through the Cleveland National Forest and private land to El Capitan Reservoir where the tunnel portals out.

3.4.2 Jurisdictional Land Use Issues

The major jurisdictional land use permitting issues associated with Corridor 5A are as follows:

- Crossing Anza-Borrego Desert State Park Carrizo Canyon and Jacumba Mountain WAs in a tunnel between Mileposts 22-28.

Issues associated with tunneling under Anza-Borrego Desert State Park WAs are the same as those addressed for Corridor 3A.

3.5 Corridor 5C West of Parallel Canal Corridor

3.5.1 General Land Use Description

Corridor 5C, which uses trenching for its entire length, begins at the end of the All-American Canal and extends west through privately owned land for a short distance, then crossing BLM land. The corridor intersects (SR) 98 and follows the road ROW to the community of Ocotillo. Land on the north side of the road ROW in this area is part of the BLM Yuha Desert WA and land on the south side of the road ROW is part of the BLM Jacumba WA. At Ocotillo, land on either side of the road ROW becomes privately owned. After exiting the Ocotillo community, the corridor heads south through the Yuha Desert Recreation Area. The corridor briefly rejoins the Interstate 8 ROW before entering San Diego County.

In San Diego County, the corridor crosses privately owned land, and, for a short distance, the BLM Jacumba National Cooperative Land and Wildlife Management Area. The corridor continues through privately owned land in the Jacumba community, crossing a small area of BLM land at Rattlesnake Mountain. The corridor then re-enters privately owned land until it crosses BLM land near Smith Canyon. The corridor then continues northwest through predominately privately owned land and small areas of BLM land before entering the Cleveland National Forest. After exiting the Cleveland National Forest, the corridor continues north through privately owned land, crossing Interstate 8 and entering the El Capitan Reservoir.

3.5.2 Jurisdictional Land Use Issues

The major jurisdictional land use permitting issue associated with Corridor 5C is passing between the two BLM WAs between about Mileposts 15-18 following (SR) 98. This section of the pipeline would need to be located outside of the two WAs. As long as the pipeline was located outside of the boundaries of the two WAs, no significant permitting problems related to jurisdictional land use are associated with this corridor. The specific boundaries of the two BLM WAs need to be established in order to verify that sufficient area is available to route the water pipeline through this area. In addition, this corridor departs from BLM Utility Planning Corridor N, which is located east and north of the two BLM WAs. This is probably not a problem, but needs to be confirmed with the BLM in more detailed discussions.

4.0 Geologic Characterization

4.0 Geologic Characterization

This section provides a geologic characterization of the alternate corridors. Corridors 3A, 3B, 5A, and 5C begin at Drop 1 on the All-American Canal (AAC). However, extending these corridors eastward along the AAC to the Colorado River at Imperial Dam is also considered. Therefore, the discussions in this section encompass the corridors from Imperial Dam to either San Vicente Reservoir or the second San Diego aqueduct. The term "Parallel Canal Corridor" is used in this section to refer to that portion of each corridor constructed as canal and aligned parallel to the AAC, Westside Main Canal, Thistle Canal, and the Trifolium Extension.

4.1 Physiographic Setting

The locations of Corridors 3A, 3B, 5A, and 5C are shown on Plates 4-1 and 4-2, which are included at the end of this section. The location of Corridor 1A is shown on Figure 2-1. A description of the geologic conditions, rock types, and geologic hazards along Corridor 1A and the Parallel Canal Corridor are discussed separately in Sections 4.4 and 4.5, respectively. The study area for the project contains a wide variety of topographic and geologic conditions ranging from moderate to high relief mountains underlain by hard rock formations to relatively flat valley floors underlain by soft alluvium and soft rock sediments.

The five alternate corridors (1A, 3A, 3B, 5A, and 5C) are located within the Basin and Range, Colorado Desert and Transverse Ranges Physiographic provinces of California. With the exception of Corridor 1A, which starts at Lake Havasu on the Colorado River, the corridors start in the Salton Trough, which is a large structural depression within the Colorado Desert province that extends from near Palm Springs to the Gulf of California in Mexico. Much of the flat floored Salton Trough is below sea level and is underlain by lakebed deposits from the ancient Lake Coahuilla. As the corridors head eastward they cross the western portion of the Salton Trough and Borrego Valley (Corridors 3A/3B) which generally consists of marine and nonmarine sediments deposited during Quaternary and Tertiary fluctuations in sea level. This area is characterized by low rolling hills, gently sloping alluvial fans, and easterly flowing washes.

West of the Colorado Desert province, the corridors enter the Peninsular Ranges province, which extends from the Los Angeles Basin to the tip of Baja California. This province is characterized by a northwest trending geologic fabric and northwest trending mountains and valleys. With the exception of the coastal plain within the metropolitan area of San Diego, the Peninsular Ranges in the study area are mainly underlain by igneous and metamorphic rocks.

4.1.1 Corridors 3A and 3B West of Parallel Canal Corridor

Corridors 3A and 3B extend from the Parallel Canal Corridor at the end of the Trifolium Extension Canal and follow State Route (SR) 78. At County Highway S-3 the Corridors 3A and 3B separate. Corridor 3A follows S-3 across the relatively flat terrain of Borrego Valley. West of Borrego Springs Corridor 3A goes into tunnel and passes beneath the San Ysidro Mountains, the northern end of the Volcan Mountains, south of Warner Basin, beneath Guejito Valley and Valley Center, and through the Merriam Mountains to the Diversion Structure. A riser shaft and flow control facility would be located near Valley Center to provide a discharge point to a new reservoir at Moosa Canyon.

From its separation point with Corridor 3A, Corridor 3B generally follows SR 78 and San Felipe wash to Sentenac Canyon where it enters a 2 mile long tunnel to avoid the narrow, winding gorge and sensitive environmental habitat along this reach. The corridor then rejoins SR 78 to the community of Banner. From this point the corridor goes into tunnel and passes beneath the Cuyamaca Mountains to where it portals out at San Vicente Reservoir. Corridor 3B extends westward from the San Vicente Reservoir to the Second San Diego Aqueduct along the proposed Emergency Storage Project (ESP) Beeler Canyon Tunnel. The ground surface along Corridors 3A and 3B reach a maximum elevation of approximately 4,200 and 4,800 feet, respectively, with maximum tunnel cover ranging up to 3,400 and 2,000 feet, respectively. A summary of the tunnel lengths and shaft depths for each alternative is provided in Table 4-1.

4.1.2 Corridor 5A West of Parallel Canal Corridor

Corridor 5A extends from the Parallel Canal Corridor at the Westside Main Canal in open cut pipeline at Dixieland and crosses the low relief terrain of the Salton Trough to the town of Ocotillo. Corridor 5A then turns northwesterly following County Highway S-2 over Sweeny Pass in pipeline to Carizzo Creek where it turns west for about 1-½ miles before going into tunnel. The tunnel then heads southwesterly and passes beneath the Tierra Blanca Mountains and In-Ko-Pah Mountains, and then turns west beneath the Laguna Mountains and southern end of the Cuyamaca Mountains to San Vicente Reservoir. Corridor 5A then extends westward from San Vicente Reservoir to the Second Aqueduct utilizing the same route as Corridor 3B. The ground surface elevation along this corridor reaches a maximum of approximately 5,200 feet near Mount Laguna and a maximum tunnel cover of 4,200 feet.

Table 4-1
Alternate Corridor Tunnel Summaries

TUNNEL SEGMENT IDENTIFICATION	DESCRIPTION AND MILEPOST	SEGMENT LENGTH (FEET)	SHAFT DEPTH (FEET)	TUNNEL GRADE (PERCENT)
CORRIDOR 3A: BORREGO SPRINGS TO I-15 (LENGTH = 219,120 FEET OR 41.5 MILES)				
3A-1	PORTAL 50.3 TO SHAFT 58.0	40,660	SHAFT 58.0 = 2,868	0.08
3A-2	SHAFT 58.0 TO SHAFT 65.0	37,220	SHAFT 65.0 = 2,302	0.08
3A-3	SHAFT 65.0 TO SHAFT 72.6	39,860	SHAFT 72.6 = 2,594	0.08
3A-4	SHAFT 72.6 TO SHAFT 80.2	40,130	SHAFT 80.2 = 1,007	0.08
3A-5	SHAFT 80.2 TO SHAFT 87.8	40,390	SHAFT 87.8 = 375	0.08
3A-6	SHAFT 87.8 TO PORTAL 91.8	20,860	N/A	0.08
CORRIDOR 3A: I-15 TO DIVERSION STRUCTURE (LENGTH = 11,300 FEET OR 2.1 MILES)				
TUNNEL SEGMENT IDENTIFICATION	DESCRIPTION AND MILEPOST	SEGMENT LENGTH (FEET)	SHAFT DEPTH (FEET)	TUNNEL GRADE (PERCENT)
3A-7	PORTAL 92.0 TO PORTAL 94.2	11,300	N/A	1.95
CORRIDOR 3B: SENTENAC CANYON (LENGTH = 9,600 FEET OR 1.8 MILES)				
TUNNEL SEGMENT IDENTIFICATION	DESCRIPTION AND MILEPOST	SEGMENT LENGTH (FEET)	SHAFT DEPTH (FEET)	TUNNEL GRADE (PERCENT)
3B-1	PORTAL 51.7 TO PORTAL 53.5	9,600	N/A	5.2
CORRIDOR 3B: BANNER GRADE TO SAN VICENTE RESERVOIR (LENGTH =128,600 FEET OR 24.4 MILES)				
TUNNEL SEGMENT IDENTIFICATION	DESCRIPTION AND MILEPOST	SEGMENT LENGTH (FEET)	SHAFT DEPTH (FEET)	TUNNEL GRADE (PERCENT)
3B-2	PORTAL 60.0 TO SHAFT 68.6	45,200	SHAFT 68.8 = 1,485	3.3
3B-3	SHAFT 68.6 TO SHAFT 76.4	41,200	SHAFT 76.4 = 1,315	3.3 / 0.15
3B-4	SHAFT 76.4 TO PORTAL 84.4	42,200	N/A	0.15
CORRIDOR 5A: TIERRA BLANCA MOUNTAINS TO CHOCOLATE CYN. (LENGTH = 178,740 FEET OR 33.9 MILES)				
TUNNEL SEGMENT IDENTIFICATION	DESCRIPTION AND MILEPOST	SEGMENT LENGTH (FEET)	SHAFT DEPTH (FEET)	TUNNEL GRADE (PERCENT)
5A-1	PORTAL 29.9 TO SHAFT 37.0	37,500	SHAFT 37.0 = 3,440	0.11
5A-2	SHAFT 37.0 TO SHAFT 45.4	44,340	SHAFT 45.4 = 3,030	0.11
5A-3	SHAFT 45.4 TO SHAFT 52.0	34,850	SHAFT 52.0 = 2,730	0.11
5A-4	SHAFT 52.0 TO SHAFT 58.1	31,950	SHAFT 58.1 = 1,750	0.11
5A-5	SHAFT 58.1 TO PORTAL 63.8	30,100	N/A	0.11
CORRIDOR 5A: CHOCOLATE CYN. TO SAN DIEGO RIVER (LENGTH = 18,200 FEET OR 3.5 MILES)				
TUNNEL SEGMENT IDENTIFICATION	DESCRIPTION AND MILEPOST	SEGMENT LENGTH (FEET)	SHAFT DEPTH (FEET)	TUNNEL GRADE (PERCENT)
5A-6	PORTAL 63.9 TO PORTAL 67.4	18,200	N/A	1.1
CORRIDOR 5A: SAN DIEGO RIVER TO SAN VICENTE RESERVOIR (LENGTH = 18,700 FEET OR 3.5 MILES)				
TUNNEL SEGMENT IDENTIFICATION	DESCRIPTION AND MILEPOST	SEGMENT LENGTH (FEET)	SHAFT DEPTH (FEET)	TUNNEL GRADE (PERCENT)
5A-7	PORTAL 68.1 TO PORTAL 71.6	18,700	N/A	0.53
BEELER CYN. PIPELINE: SAN VICENTE RES. TO SECOND AQUEDUCT (LENGTH = 55,500 FEET OR 10.5 MILES)				
TUNNEL SEGMENT IDENTIFICATION	DESCRIPTION AND MILEPOST	SEGMENT LENGTH (FEET)	SHAFT DEPTH (FEET)	TUNNEL GRADE (PERCENT)
ESP-1	PORTAL 0.0 TO SHAFT 1.3	6,600	SHAFT 1.3 = 45	0.53
ESP-2	SHAFT 1.3 TO SHAFT 3.5	12,000	SHAFT 3.5 = 40	0.95
ESP-3	SHAFT 3.5 TO SHAFT 7.3	19,800	SHAFT 7.3 = 30	0.2
ESP-4	SHAFT 7.3 TO PORTAL 10.5	17,100	N/A	0.99

4.1.3 Corridor 5C West of Parallel Canal Corridor

Corridor 5C extends from the Parallel Canal Corridor in pipeline at the end of the All-American Canal and crosses relatively flat terrain parallel to Highway 98 to Ocotillo. It then turns southwest and climbs the steep, rugged terrain along In-Ko-Pah Gorge to the town of Jacumba where it then generally follows the Mexican border, still in pipeline over the Jacumba Mountains and Tecate Divide reaching a maximum elevation of approximately 4,600 feet. Corridor 5C then turns northwesterly at Campo and Potrero passing near Barrett Lake and Loveland Reservoir to Chocolate Canyon and then on to San Vicente Reservoir in tunnel. From San Vicente Reservoir, Corridor 5C will extend to the Second San Diego Aqueduct along the proposed ESP Beeler Canyon Tunnel utilizing the same route as Corridors 3B and 5A.

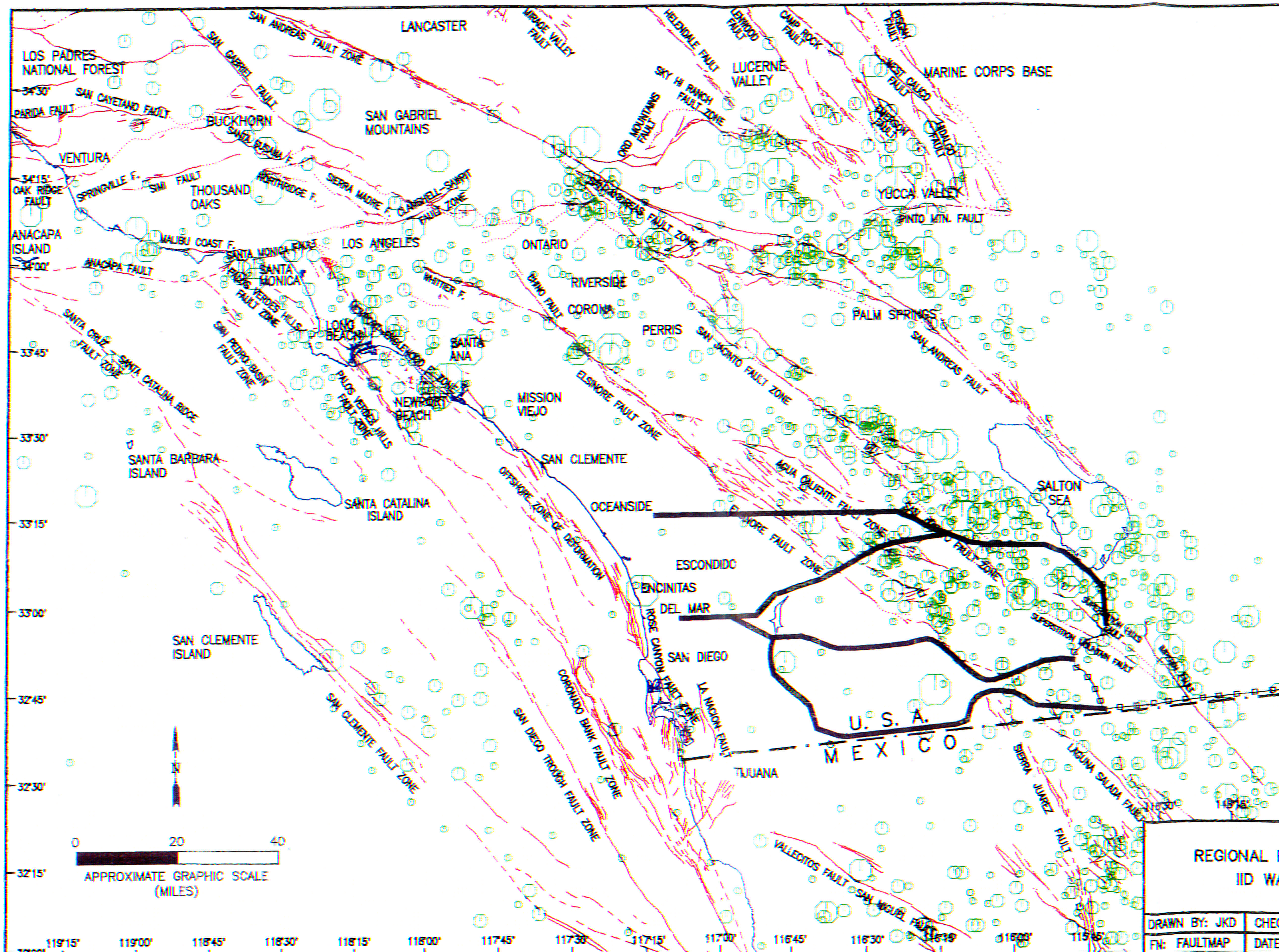
4.2 Seismic Considerations

4.2.1 Seismic Setting

The Imperial Valley and Peninsular Ranges are seismically active regions where many historical earthquakes have occurred. Figure 4-1 is a regional fault map that depicts the alternate alignments with respect to major active faults.

Imperial Valley lies within a tectonic feature known as the Salton Trough. The active faults that pass through the Salton Trough together accommodate a substantial portion of the plate tectonic movement and between the Pacific and North American tectonic plates. Consequently, the historical seismicity of the Imperial Valley has been high. Since about the 1930s, at least eight large (M6 or greater) earthquakes have occurred in the Salton Trough. Moreover, based on felt intensity accounts and paleoseismic studies, nearby areas (including the Peninsular Ranges and Imperial Valley) are believed to have produced major earthquakes before seismograph recordings were available. Several earthquakes, including an earthquake in 1892, produced some of the most strongly felt seismic shaking in relatively distant coastal areas of San Diego County.

At the approximate latitudes of the corridors under evaluation, the active strands of the San Jacinto and Elsinore fault zones will be traversed along the western margin of the Salton Trough. These two active fault systems, in conjunction with the San Andreas fault near the Salton Sea, and major active faults in Baja California and coastal San Diego County, all represent seismic shaking hazards. However, the alternate routes cross active strands of the San Jacinto and Elsinore fault zones. Due to their recency (i.e., recognized past displacement within the last 11,000 years) and repeated historical earthquakes producing fault surface rupture (San Jacinto fault zone) these two fault zones represent significant fault rupture hazards within a time frame comparable to the project design life (assumed to be a period of about 100 years).



LEGEND

REPORTED EARTHQUAKE MAGNITUDES.

- 3.0 TO 3.9
- 4.0 TO 4.9
- 5.0 TO 5.9
- 6.0 TO 6.9
- 7.0 AND GREATER

EPICENTER AND MAGNITUDE DATA ARE FROM THE CALTECH EARTHQUAKE CATALOG FOR THE PERIOD FROM 1800 TO DECEMBER 1991, WITH THE 1992 JOSHUA TREE, LANDERS, AND BIG BEAR, AND 1994 NORTHRIDGE EVENTS ADDED. ONLY EARTHQUAKES OF MAGNITUDE 3.0 AND LARGER ARE SHOWN.

? ? ?

APPROXIMATE FAULT LOCATIONS, DOTTED WHERE CONCEALED, QUERIED WHERE CONJECTURAL. FAULT LOCATIONS BASED ON: ZIONY AND JONES, 1989; GEOLOGIC MAP SERIES OF CALIFORNIA, 1977–1986 (1:250,000 SCALE); GEOLOGIC MAP SERIES, CALIFORNIA CONTINENTAL MARGIN, 1986–1987 (1:250,000 SCALE); HAUKSSON, 1990; AND WRIGHT, 1991.

CANDIDATE ALIGNMENTS

PARALLEL CANAL

REGIONAL FAULT AND EPICENTER MAP
IID WATER TRANSFER STUDY

DRAWN BY: JKD	CHECKED BY: ガ E S	FIGURE: 4-1
FN: FAULTMAP	DATE: 4-4-96	PROJECT NO: 9551144S-1500

WOODWARD-CLYDE CONSULTANTS

4.2.2 Fault Crossings

Table 4-2 summarizes characteristics of active faults which will be crossed along the various alternate routes. Table 4-2 also summarizes magnitudes of known historical earthquakes and estimated maximum earthquakes for respective fault segments. It should be recognized that the fault segments indicated on Table 4-2 represent active faults that will be crossed by the alternative corridors. More distant active faults (not actually crossed by the alternative corridors) are not included on the table.

The faults listed on Table 4-2 represent significant recognized "segments," or separate fault strands within a much longer, through-going regional fault system. For preliminary evaluations, single segment ruptures were assumed for each active fault crossing. The estimated fault displacement per event, and associated recurrence interval, assumes the maximum earthquake magnitude occurring on a given fault segment using current data which correlates earthquake magnitudes with fault length. This approach is consistent with the characteristic earthquake hypothesis in which slip along a fault is dominated by earthquakes that rupture an entire fault segment. This characteristic earthquake model provides an estimate of the likely large magnitude event given the assumption that slip on a fault is dominated by earthquakes that rupture entire segments with a characteristic displacement. This approach provides a better estimate of likely large events for a given fault than the notion of Maximum Probable Earthquake.

Ruptures involving longer multisegmented strands of regional fault zones are possible, albeit less likely, and would result in earthquake magnitudes and associated displacements greater than indicated in Table 4-2. These multisegment fault ruptures represent maximum credible earthquake estimates. For example, a multiple segment rupture along the Elsinore Fault zone involving the Temecula and Julian segments could generate an M7¼ earthquake with associated maximum displacements of approximately 15 feet. This type of rupture represents a rare event that produces much larger displacements than those anticipated design level scenarios.

4.3 Ground Conditions

The geologic formations along the candidate corridors are shown on Plates 4-1 and 4-2. These plates also show the mapped faults in the project area along with known hot springs and wells and mapped or suspected landslides within the corridor study area. The geologic formations within the study area can be divided into three categories of ground conditions for tunneling assessment:

- Unconsolidated to poorly consolidated soft ground sedimentary deposits.
- Slightly to moderately indurated soft rock sediments.
- Weathered to fresh, hard metamorphic and igneous volcanic and intrusive rocks

Table 4-2
Summary of Fault Crossings

Fault Name	Pipeline/Tunnel Crossing	Fault Classification*	Fault Activity**	Fault Length (km)	Slip Rate (mm/year)	Estimated Maximum Historic Earthquakes (year)	Maximum Earthquake Magnitude (MW)	Estimated Displacement per Event (feet)	Estimated Recurrence Interval (years)
Elsinore Fault Zone									
Julian Segment	Tunnel	R	A	85	5	--	7.0	6	360
Coyote Mountain Segment	Pipeline	R	A	32	4	--	6.6	8	625
Laguna Salada Segment	Pipeline	R	A	71	4	7.0 (1892)	6.7	3	230
Earthquake Valley Fault	Pipeline	R	A	20	N/A	--	6.2	1 - 2	N/A
San Jacinto Fault Zone									
Borrego Mountain Segment	Pipeline	R	H	49	4	6.4 (1968)	6.5	2 - 3	175
Elmore Ranch Fault	Pipeline	R	H	10	N/A	6.2 (1987)	6.2	<1	N/A
Imperial Fault	Canal	R	H	96	30	6.8 (1940)	7.0	6	60

Notes:

*R = Strike slip right lateral.

**Activity Abbreviations = A = Active, H = Historic.

References:

Anderson and others, 1989.
Jennings, 1994.
Woodward-Clyde, 1994.
SCEC, 1995.

4.3.1 Soft Ground Sedimentary Deposits

The soft ground sediments include the unconsolidated to poorly consolidated clay, silt, sand, gravel, and boulder deposits that occur as alluvial deposits, lake bed deposits, and older alluvial fan and terrace deposits. These materials would be encountered along the canal and open cut pipeline sections primarily in the Salton Trough and Borrego Valley areas as shown on Plates 4-1 and 4-2. The finer grained lake deposit occur mostly below sea level on Corridors 3A/3B along the Trifolium Extension, SR 86 and SR 78. The lake deposits consist mainly of silt and clay with interbeds of sand and gravel. East of these deposits, above sea level to the mountain front, the pipeline corridors will encounter primarily alluvium deposits. Along the low relief sections of the corridors such as 5C between the All-American Canal and Ocotillo, 5A between Dixieland to Sweeny Pass, and 3B along SR 78 and S-3 through Borrego Valley the alluvium consists of mostly silt, sand, and gravel with some reaches of older dissected terrace and alluvial fan deposits The alluvium tends to become more coarse grained with cobbles and boulders closer to the mountains and in the major washes such as San Felipe Wash along Corridor 3B, and where Corridor 5A crosses Carrizo and Bow Willow creeks. Alluvial deposits which would be encountered in Corridor 5C also occur in the mountain valleys near Jacumba and Potrero in addition to major drainages crossed by the pipeline

The soft ground sediments are generally loose, are easily excavated, and will probably require immediate support in excavations unless the sides of the excavations can be sloped The occurrence of large boulders in the alluvial deposits could potentially impede the progress of soft ground excavations and also generate oversize material requiring special handling and disposal.

4.3.2 Soft Rock Sedimentary Deposits

The soft rock sediments in the study area include weakly cemented to moderately indurated Pleistocene age claystones and sandstones of the Brawley Formation and sandstones and conglomerates of the Ocotillo Formation, and older Tertiary age claystone, sandstone, and conglomerates of the Borrego Formation, Palm Springs Formation, Canebrake Conglomerate, and Table Mountain Formation. With the exception of the Stadium Conglomerate, these sediments occur as isolated deposits and are crossed by the pipeline corridor near the town of Ocotillo Wells, at Sweeny Pass, near the town of Jacumba, and in the Yuha Desert west of the All-American Canal as shown on Plate 4-2.

Similar to the soft ground sediments, the soft rock sediments should be relatively easy to excavate; however, they should require less trench support. The conglomerate formations contain oversize cobbles and boulders that may complicate excavation and backfill operations. The Stadium Conglomerate will be encountered along much of the Beeler Canyon Tunnel alignment as shown on Plate 4-1.

4.3.3 Hard Metamorphic and Igneous Rocks

The hard rock formations have been subdivided into six general categories and include: volcanic rock, gabbro, undifferentiated granitic rocks, hybrid gneissic and granitic rocks, metavolcanic rock, and metasedimentary rocks. These hard rocks all occur in the mountainous area west of the Salton Trough and would be encountered in the tunnel segments of each corridor with the exception of Corridor 5C which is the open cut alternative over the mountains. The mapped locations of the various rock units are shown on Plates 4-1 and 4-2. Table 4-3 includes a summary of the estimated length of tunnel in each rock type for the alternative corridors.

4.3.3.1 Volcanic Rocks. The Miocene age volcanic rocks are of limited areal extent and are mapped principally in the area surrounding Jacumba Valley and near the town of Ocotillo. These rocks are not mapped along any of the tunnel corridors and would be crossed only by the 5A and 5C open cut pipeline in very localized areas. The volcanic rocks consist of interlayered and mixed andesite, basalt, volcanic breccia, and cinder cones. The volcanic breccia and cinder cones could likely be excavated with conventional heavy-duty equipment without the need for blasting. The andesite and basalt may require blasting where fresh rock is near the ground surface; however, the depth and degree of weathering is expected to be significant and blasting would probably be needed only in very localized areas.

4.3.3.2 Gabbro and Undifferentiated Granitic Rocks. As indicated in Table 4-3 the gabbro and undifferentiated granitic rocks are the principal hard rock types that occur west of the Salton Trough. These Cretaceous age crystalline rocks are part of the southern California batholith and are the core of the Peninsular Range Province. The gabbro is a dark colored rock with abundant mafic minerals and typically less then 5 percent quartz. The gabbro occurs as isolated plutons within the undifferentiated granitic rocks ranging from less than a mile to several miles across. The undifferentiated granitic rocks range compositionally from tonalite to granodiorite to quartz monzonite. They are generally light gray to gray colored, fine to coarse grained, and contain up to 40 percent quartz.

Table 4-3
Summary of Geologic Conditions Along Tunnel Corridors

CORRIDOR 3A: BORREGO SPRINGS TO DIVERSION STRUCTURE

TUNNEL SEGMENT IDENTIFICATION	MILEPOST	APPROXIMATE LENGTH OF TUNNEL IN EACH GEOLOGIC UNIT (FEET)							
		PLIOCENE SEDIMENTS	MIOCENE VOLCANICS	OLDER TERTIARY SEDIMENTS	CRETACEOUS GABBROIC ROCK	CRETACEOUS GRANITIC ROCKS, UNDIVIDED	HYBRID ROCK, GNEISSIC GRANITICS	JURASSIC METAVOLCANICS	PREBATHOLITIC METASEDIMENTS
3A-1	50.3 TO 58.0					40,660			
3A-2	58.0 TO 65.0					22,010	14,420		
3A-3	65.0 TO 72.6				6,580	23,720	6,000		4,000
3A-4	72.6 TO 80.2				8,170	29,300	830		2,920
3A-5	80.2 TO 87.8				1,750	38,660			
3A-6	87.8 TO 91.8				1,000	24,340			
3A-7	92.0 TO 94.2					9,970		1,330	

CORRIDOR 3B: BANNER GRADE TO SAN VICENTE RESERVOIR

TUNNEL SEGMENT IDENTIFICATION	MILEPOST	APPROXIMATE LENGTH OF TUNNEL IN EACH GEOLOGIC UNIT (FEET)							
		PLIOCENE SEDIMENTS	MIOCENE VOLCANICS	OLDER TERTIARY SEDIMENTS	CRETACEOUS GABBROIC ROCK	CRETACEOUS GRANITIC ROCKS, UNDIVIDED	HYBRID ROCK, GNEISSIC GRANITICS	JURASSIC METAVOLCANICS	PREBATHOLITIC METASEDIMENTS
3B-1	51.7 TO 53.5						9,600		
3B-2	60.0 TO 68.6				7,500		6,220		16,780
3B-3	68.6 TO 76.4					8,750	27,880		
3B-4	76.4 TO 84.4								

CORRIDOR 5A: TIERRA BLANCA MOUNTAINS TO CHOCOLATE CANYON

TUNNEL SEGMENT IDENTIFICATION	MILEPOST	APPROXIMATE LENGTH OF TUNNEL IN EACH GEOLOGIC UNIT (FEET)							
		PLIOCENE SEDIMENTS	MIOCENE VOLCANICS	OLDER TERTIARY SEDIMENTS	CRETACEOUS GABBROIC ROCK	CRETACEOUS GRANITIC ROCKS, UNDIVIDED	HYBRID ROCK, GNEISSIC GRANITICS	JURASSIC METAVOLCANICS	PREBATHOLITIC METASEDIMENTS
5A-1	29.0 TO 37.0					40,000			
5A-2	37.0 TO 45.4					34,440	7,170		4,670
5A-3	45.4 TO 52.0								

Table 4-3 (Continued)
Summary of Geologic Conditions Along Tunnel Corridors

CORRIDOR 5A: TIERRA BLANCA MOUNTAINS TO CHOCOLATE CANYON (CONTINUED)

TUNNEL SEGMENT IDENTIFICATION	MILEPOST	APPROXIMATE LENGTH OF TUNNEL IN EACH GEOLOGIC UNIT (FEET)							
		PLIOCENE SEDIMENTS	MIOCENE VOLCANICS	OLDER TERTIARY SEDIMENTS	CRETACEOUS GABBROIC ROCK	CRETACEOUS GRANITIC ROCKS, UNDIVIDED	HYBRID ROCK, GNEISSIC GRANITICS	JURASSIC METAVOLCANICS	PREBATHOLITIC METASEDIMENTS
5A-4	52.0 TO 58.1					21,440			
5A-5	58.1 TO 63.8				3,750	31,250			

CORRIDOR 5A/5C CHOCOLATE CANYON TO SAN VICENTE RESERVOIR

TUNNEL SEGMENT IDENTIFICATION	MILEPOST	APPROXIMATE LENGTH OF TUNNEL IN EACH GEOLOGIC UNIT (FEET)							
		PLIOCENE SEDIMENTS	MIOCENE VOLCANICS	OLDER TERTIARY SEDIMENTS	CRETACEOUS GABBROIC ROCK	CRETACEOUS GRANITIC ROCKS, UNDIVIDED	HYBRID ROCK, GNEISSIC GRANITICS	JURASSIC METAVOLCANICS	PREBATHOLITIC METASEDIMENTS
5A-6	63.9 TO 67.4								
5A-7	68.1 TO 71.6								
5C-1	83.8 TO 87.3								
5C-2	87.9 TO 91.4					37,500			

BEELER CYN. PIPELINE: SAN VICENTE RES. TO SECOND AQUEDUCT

TUNNEL SEGMENT IDENTIFICATION	MILEPOST	APPROXIMATE LENGTH OF TUNNEL IN EACH GEOLOGIC UNIT (FEET)							
		PLIOCENE SEDIMENTS	MIOCENE VOLCANICS	OLDER TERTIARY SEDIMENTS	CRETACEOUS GABBROIC ROCK	CRETACEOUS GRANITIC ROCKS, UNDIVIDED	HYBRID ROCK, GNEISSIC GRANITICS	JURASSIC METAVOLCANICS	PREBATHOLITIC METASEDIMENTS
ESP-1	0.0 TO 1.3					8,900			
ESP-2	1.3 TO 3.5			7,300		4,300			
ESP-3	3.5 TO 7.3			20,000					
ESP-4	7.3 TO 10.5			8,000		7,900		1,000	

The intrusive gabbroic and granitic rocks are usually very hard when not weathered. However, most of the surface exposures are deeply weathered to a weak, friable material that looks like rock but has engineering properties similar to a very dense, sandy soil. Rounded, very hard rock bodies (core stones) are present locally in this sandy soil matrix, and are the remains of the original fresh rock. These core stones range in size from less than a foot to over 10 feet in diameter. Their size and frequency increase with depth until the entire rock mass is hard and unweathered.

The 5C pipeline corridor is almost entirely located within the granitic and gabbroic rocks from Ocotillo to El Capitan Reservoir except in the Jacumba Valley area. As described above, these rocks are expected to be weathered near the ground surface and blasting would be required where core stones need removal and in areas where the weathered rock has been removed by erosion such as on steep slopes and in canyon bottoms.

Information is limited regarding the characteristics of the fresh granitic and gabbroic rocks at the depth of the tunnels, particularly the rock strength and/or the rock mass jointing. Based on past experience with granitic type rocks in San Diego County, the unweathered rocks are expected to have relatively high unconfined compressive strengths ranging from 15,000 to 50,000 pounds per square inch (psi). The rock jointing or discontinuities at the depths of the tunnels are also expected to be widely spaced and the rock to be of high quality except in the vicinity of faults and shears.

4.3.3.3 Metamorphic Rocks. The metamorphic rocks include the hybrid, metavolcanic, and metasedimentary rocks The hybrid rocks (mixed rocks) are mapped along tunnel portions of Corridors 3A and 3B and for a short reach along Corridor 5A. In general, this unit includes two types of rock: migmatite to banded gneiss and rocks that are mainly mixed granitic rocks with bodies of metamorphic rock containing schist and gneiss. These rocks are pervasively jointed and foliated near the surface and tend to weather more deeply than the above described granitic and gabbroic rocks. However, these rocks are expected to be hard and unweathered at tunnel depth except where encountered at a portal.

The metavolcanic rock includes the Santiago Peak Volcanics composed of mildly metamorphosed volcanic, volcaniclastic, and associated intrusive rocks. These rocks occur mainly in western San Diego County and are crossed only by a short section of tunnel near Interstate 15 on Corridor 3A. These rocks are typically fine grained, blocky, and very hard with unconfined compressive rock strengths commonly in the 20,000 to 40,000 psi range

The metasediments include the oldest rocks in the study area and include both the Julian Schist in the eastern part of San Diego County and the Bedford Canyon Formation in the northwest part of the county. These rocks occur as inclusions, pendants, and screens which are bounded by younger granitic rocks. As indicated in Table 4-3, the metasediments (Julian Schist) have been mapped along a significant segment of Corridor 3B in the Julian area and for a short reach on Corridor 5A. Metasediments associated with the Bedford Canyon Formation occur along a short reach of Corridor 3A west of Warner Basin. The metasedimentary rocks are predominately quartz-mica schist with lesser amounts of gneiss, quartzite, phyllite, and limestone. These rocks are pervasively jointed and foliated and are deeply weathered. They are expected to be generally unweathered at tunnel depth; however, the pervasive foliation may impart an overall weakness to this rock type requiring more support in a tunnel than the other rock types previously described.

4.3.4 Faults and Shears

One of the key criteria in laying out the candidate corridors was to avoid, where possible, crossing active faults in tunnel to minimize the risk of encountering hot water associated with faults in the study area, and to limit future repairs in the event of fault rupture to more easily managed cut-and-cover pipelines. The only unavoidable tunnel crossing of a known active fault was on Corridor 3A where the Elsinore fault is crossed. As indicated in Table 4-2, the estimated displacement of this segment of the Elsinore fault is approximately 6 feet with an estimated recurrence interval of 360 years. Other active faults crossed in pipeline are included in Table 4-2.

We recommend that fault rupture hazards be further addressed in future studies. In particular, more detailed risk assessments should be performed to evaluate the relative likelihood that one or more of the active fault crossings may produce fault surface rupture within a time frame of significance to the proposed project.

Plates 4-1 and 4-2 show the location and orientation of the known major mapped faults. Although faults and shears are not a specific rock type, they are important in the characterization of tunnel ground conditions because they can alter the strength and tunneling performance of the rock mass and, therefore, affect construction cost and schedule estimates. The fault or shear planes, and/or the close jointing often associated with fault or shear zones, may ravel or combine to produce fallouts of rock wedges leading to tunnel overexcavation or overbreak. Tunnel overbreak occurs when weak or jointed rock falls into the tunnel excavation from beyond the limits of the intended excavation. This tends to occur most extensively in the crown or top portion of the tunnel. The shearing and fracturing associated with a fault zone can cause an otherwise very hard rock to behave as soft ground Clay gouge seams which are often found in fault and shear zones can swell or squeeze when wet, or contract and slake when dry. Faulting and shearing can pulverize otherwise hard competent rock, produce running ground, or flowing ground if groundwater is present. The clay gouge in the fault zones, which is relatively impermeable, impounds groundwater moving through the discontinuities of the rock mass. Faults can act as groundwater barriers, ponding or storing water on one side of the fault, while the other side has significantly less water. Thus, groundwater inflows to the tunnel excavation could be substantially greater on the "wet" side of the fault than on the "dry" side. The groundwater ponding condition could also lead to higher volume/higher pressure groundwater inflows into the tunnel if the fault is penetrated from the "dry" side.

The majority of the faults are crossed in a favorable orientation, being as close to perpendicular as possible. It is not desirable to excavate a tunnel in a fault zone parallel to its trend Weak ground conditions (such as gouge, breccia, and shattered rock, and the potential for high groundwater inflows), would follow the tunnel advance and cause significant increases in construction cost and delay.

4.3.5 Groundwater

Groundwater is likely to be encountered within the excavated trench depths along the pipeline and canal sections below sea level near the All-American Canal and the Trifolium Extension. Groundwater can also be anticipated in the major drainage crossings along Corridor 5C such as Cottonwood Creek below Barrett Reservoir and the Sweetwater River. Some of the major desert washes such as San Felipe Creek and Carizzo Creek may also have a seasonally shallow water table.

All of the tunnels, with the possible exception of the short tunnel parallel to Sentenac Canyon on Corridor 3B, will be below the regional groundwater table and groundwater inflows can be expected. In these hard rock tunnels groundwater inflows are likely to occur in the fault zones and in other areas where the rock mass is highly fractured adjacent to faults. One of the largest unknown factors at this time is the volume, pressure, and duration of groundwater inflow into the tunnels. In order for groundwater to flow in the hard rock mass, the fractures in which water is present must be open and interconnected Fracture frequency and openness are generally expected to decrease with depth due to the overburden stresses on the rock mass; therefore, permeability is also expected to decrease with depth As a result, most groundwater and groundwater inflow is expected to be perched in the more highly fractured near-surface rock mass, and large volume inflows are expected only in the vicinity of faults.

Although larger in diameter than the tunnels planned for this project, the groundwater inflows during construction of Metropolitan Water District's San Jacinto and San Bernardino Tunnels is a comparison of the magnitude of possible groundwater inflows Both of these tunnels were excavated in hard granitic and metamorphic rocks similar to those that would be encountered along the alternative corridors. These tunnels were also mined using drill-and-blast methods rather than a tunnel boring machine, which is believed to increase the rock mass permeability and thus the groundwater inflows. The San Bernardino Tunnel is approximately 20,000 feet in length, 18 foot excavated diameter, with 2,000 feet maximum cover. This tunnel experienced maximum groundwater inflows of 1,800 gallons per minute (gpm) at a pressure of 400 psi. The San Jacinto Tunnel which is 68,800 feet long, 20 foot excavated diameter, with a maximum cover of 2,700 feet encountered a maximum inflow of 16,000 gpm at pressures ranging up to 600 psi. These high inflows to the San Jacinto tunnel caused a delay in construction for nearly a year. Essentially all of the significant groundwater inflows in these tunnels were associated with faults that crossed the alignments or the highly fractured rock mass in the vicinity of the faults.

There are several mapped springs throughout the region above the alternative tunnel corridors and the tunnels also pass beneath several alluvial filled valleys which contain a shallow groundwater table. Some of the more significant valleys include the Warner Basin, Pine Valley, Samataguma Valley, and Valley Center. In areas where faults intercept these near-surface groundwater features, it must be assumed that the full hydrostatic head of the groundwater may be experienced at tunnel depth. A dewatering of the surface groundwater resources is another issue which needs to be considered. A loss of groundwater resources from both an economic and environmental standpoint is an important issue which needs to be considered during future studies. Much of the area above the tunnel corridors is fully dependent on wells as the only source of water.

4.3.6 Landslides

Landslides are unlikely along the eastern portions of the open cut corridors in the Salton Trough due to the subdued topography traversed by the pipelines. As the corridors approach the Peninsular Ranges, landslides become a more significant hazard in the steep, mountainous terrain. Since landslides are surficial features normally confined to the upper weathered rock materials, only the open cut section of the pipeline and the tunnel portals or shafts are impacted.

A review of regional published geologic maps indicate that the only mapped landslide within the study corridor is located south of the 3B portal in the Banner Grade area. The foliated metamorphic rocks in this area, combined with the steep topography and the presence of the Elsinore fault which has fractured the surrounding rock mass, creates conditions receptive to landsliding. The mapped landslide does not affect the portal location in this area; however, a more detailed study of stereo-paired aerial photographs of this site would be warranted. Other areas where landslides may impact Corridor 5C include the steep In-Ko-Pah Gorge, and the steep canyon areas between Potrero and Chocolate Canyon.

4.3.7 Liquefaction

Liquefaction is the physical process in which a saturated, low cohesion granular material loses its strength during seismic induced ground shaking and changes from a solid state to a liquid state. This mechanical transformation and resulting loss of strength can cause various kinds of ground failure. The liquefaction process typically occurs at depths of less than 50 feet from the surface, with the most susceptible conditions occurring at depths of less than 30 feet below the surface. Liquefaction has accompanied historical earthquakes in the Imperial Valley.

Liquefaction is a potential hazard for the pipeline corridors located in alluvial or lake deposits where a high groundwater table exists. These areas include the corridors near the Salton Sea and All-American Canal generally below sea level, and in other alluvial filled valleys which may have a seasonally or permanent high groundwater table such as San Felipe Wash, Cottonwood Creek, and the Sweetwater Valley. Soil liquefaction, were it to occur, can result in sand boiling, ground subsidence, differential settlement, heave, and lateral spreading. The liquefaction susceptibility of any given location would require site-specific studies which would include a determination of depth to water and subsurface material types and engineering properties.

4.3.8 Scour and Erosion

One of the issues concerning the open cut pipeline corridors is the identification of stream crossings which may be subject to scour by runoff from extreme storm events. Scour is related to a number of stream characteristics, including bottom slope, channel material composition, discharge quantity, amount of stabilizing vegetation in the stream, the sediment transport capacity of the flow, the degree to which the streambed has been altered by dredging or sand mining operations, and the degree to which the storm flow is channelized in the stream bed. Potential scour depths tend to be greater in unvegetated streams with fine grained channel materials, large channel slopes, and for storms with longer recurrence intervals. Scour can also be increased at a bend due to the hydro-dynamic forces of the water flowing along the bend.

Almost all of the major stream crossings along the open cut pipeline sections are expected to be subject to some amount of scour during extreme storm events. However, in general the potential for scour is expected to be greatest in the washes on the eastern slopes of the mountains and at the crossing of the Sweetwater River below Loveland Dam and the San Diego River below El Capitan Reservoir. The washes include Myer Creek in In-Ko-Pah Gorge on Corridor 5C; Bow Willow Creek, Carrizo Creek, and numerous other smaller washes which cross S-3 and Corridor 5A; and San Felipe Creek which is crossed by Corridor 3A and is paralleled for several miles by Corridor 3B.

4.3.9 Hot Water, High Rock Temperatures, and Gas

Hot springs and wells which tap hot water are wide spread through the study area. The location of the known hot springs and wells in the study area are shown on Plates 4-1 and 4-2. Hot water and the associated high ground temperatures present a significant hazard if encountered during tunneling. A key criterion in laying out the corridors was to avoid crossing areas of known hot water in tunnel. These areas include the hot springs in the Jacumba Valley, the Warner Hot Springs northeast of Lake Henshaw, hot springs in Cameron Valley east of Lake Morena, and a hot spring near Pauma Valley near Rincon. A preliminary review of a geochemical analysis performed on the hot spring at Jacumba by a student at San Diego State University (G. A. Swenson, 1981) indicates this spring, which has a surface temperature of 100° F, has a temperature of 195° F at a depth of 3,000 feet.

Even though the known hot spring areas have been avoided, there exists the possibility that hot water will be encountered in the tunnels, especially Corridor 3A which crosses the Elsinore fault zone in tunnel.

Another potential hazard to the tunnels is elevated rock temperatures. The rock cover along 3A and 5A tunnels generally exceeds 2,500 to 3,000 feet for significant distances. Due to the geothermal gradient in the earth's crust, the ambient rock temperature increases with increasing depth. The geothermal gradient ranges from as much as 1° F per 30 foot depth to as little as 1° F per 250 feet of depth, with the average being about 1° F per 60 foot depth. Assuming this average gradient, a surface ambient rock temperature of 60° F would result in a rock temperature of 110° F at a depth of 3,000 feet. This temperature could be higher or lower, depending on the local geothermal gradient. The only known nearby temperature measurements at the depths of the tunnels is an exploratory boring drilled by the USGS near Cajon Pass in San Bernardino County. This boring was drilled into granitic rocks similar to those that would be encountered in the tunnels Measured temperatures in the boring were 230° F at a depth of 6,000 feet and 150°F at a depth of 3,000 feet. This boring was drilled near the San Andreas fault which may have influenced the observed temperatures.

The metamorphic and granitic rocks that would be encountered along the alternative tunnel corridors are not expected to produce gas However, hydrogen sulfide gas may be encountered in areas where hot water is present. Hydrogen sulfide gas is toxic to humans and can be explosive if the concentrations are sufficient.

4.4 Corridor 1A

Corridor 1A, which would parallel the existing Colorado River Aqueduct (CRA), starts at Lake Havasu and crosses portions of the Colorado and Mojave Deserts, the northern end of the Salton Trough, and enters the Peninsular Ranges near San Gorgonio Pass. The majority of this corridor east of San Gorgonio Pass is characterized by basins of internal drainage with relatively broad, gently alluvial fans, flat playas (dry lake beds), and intervening mountain ranges The core of the mountain ranges typically consist of hard granite, volcanic and metamorphic rocks, with the surrounding alluvial fans composed of sand and gravel eroded from the nearby mountains.

North of Palm Springs the corridor crosses the northern end of the Coachella Valley and passes beneath the northern flanks of the San Jacinto Mountains in tunnel. This tunnel exits in the San Jacinto valley near the town of Hemet. The corridor then trends southward paralleling the San Diego Canal across the Perris Plain to Skinner Reservoir. Both the San Jacinto mountains and the upland areas in the Perris Plain consist of hard granite and metamorphic rocks while the low lying areas are underlain by alluvium.

As shown in profile on Figure 7-1, a parallel facility to the CRA would require reservoirs, pumping plants, canals, buried pipelines or siphons, and tunnels. Table 4-4 provides a summary of the generalized geologic units by rock type and milepost related to the type facility (e.g., canal, tunnel, siphon, etc.). The table also shows the approximate length of ground type (e.g., soft ground, soft rock, or hard rock) that each type of facility crosses.

The soft ground formations include primarily Quaternary age alluvium (Qal) and younger nonmarine sediments (Qc) consisting of alluvial fan deposits. These materials consist of silts, sands, gravels, and boulders which have been eroded from the surrounding mountains. As indicated on Table 4-4, the canals and siphons are generally in the soft ground sediments since they cross the valley floors and broad alluvial fans, and the tunnels

Table 4-4
Summary of Geologic Conditions
Corridor 1A--Colorado River Aqueduct

Structure/ Milepost	Geologic Map Unit	Soft Ground	Soft Rock	Hard Rock	Geologic Hazards
Lift 0.0 - 0.2	pCc			0.2	
Tunnel 0.2 - 0.9	pCc		0.7		
Tunnel 0.9 - 1.2	Tc		0.3		
Reservoir 1.2 - 1.6	Tc		0.4		
Lift 1.6 - 2.0	Tc		0.4		
Tunnel 2.0 -3.8	pCc			1.8	
Tunnel 3.8 - 4.5	Tc		1.2		
Reservoir 4.5 - 5.5	Tc		0.5		
Reservoir 5.5 - 6.0	pCc			0.5	
Tunnel 6.0 - 6.4	pCc			0.4	
Tunnel 6.4 - 8.0	Tc		1.6		
Tunnel 8.0 - 10.2	pCc			2.2	
Tunnel 10.2 - 10.4	Tv		0.2		
Tunnel 10.4 - 10.6	Tc		0.2		
Tunnel 10.6 - 10.8	pCc			0.2	
Tunnel 10.8 - 11	Tv			0.2	

Table 4-4 (Continued)
Summary of Geologic Conditions
Corridor 1A--Colorado River Aqueduct

Structure/ Milepost	Geologic Map Unit	Soft Ground	Soft Rock	Hard Rock	Geologic Hazards
Siphon 11 - 12.2	Tv			1.2	
Siphon 12.2 - 22.1	Qc	9.9			
Canal 22.1 - 35.5	Qc	13.4			
Canal 35.5 - 50	Qal	14.5			
Siphon 50 - 52	Qal	2.0			
Siphon 52 - 56	Qc	4.0			
Canal 56 - 62	Qc	6.0			
Canal 62 - 67.7	Qal	5.7			
Lift 67.7 - 67.9	m, gr, gr-m			0.2	
Tunnel 67.9 - 75	m, gr, gr-m			7.1	
Canal 75 - 88	Qal	13.0			
Canal 88 - 89.5	Qc	1.5			
Canal 89.5 - 92.6	Qal	3.1			
Tunnel 92.6 - 96	gr			3.4	
Canal 96 - 100	Qal	4.0			
Canal 100 - 104	Qc	4.0			

Table 4-4 (Continued)
Summary of Geologic Conditions
Corridor 1A--Colorado River Aqueduct

Structure/ Milepost	Geologic Map Unit	Soft Ground	Soft Rock	Hard Rock	Geologic Hazards
Siphon 104 - 107.5	Qc	3.5			
Siphon 107.5 - 109	Qal	1.5			
Lift 109 - 110	gr, pCc			1.0	
Tunnel 110 - 111.8	gr, pCc			1.8	
Siphon 111.8 - 112.7	gr, pCc			0.9	
Tunnel 112.7 - 118	gr, pCc			5.3	
Canal 118 - 124.3	Qal	6.3			
Lift 124.3 - 125	pCc			0.7	
Tunnel 125 - 127.8	pCc			2.8	
Siphon 127.8 - 131	Qc	3.2			
Siphon 131 - 137.5	Qal	6.5			
Siphon 137.5 - 140.5	Qc	3.0			
Tunnel 140.5 - 144.4	gr, gr-m			3.9	
Siphon 144.4 - 146.3	Qal	1.9			
Tunnel 146.3 - 148.2	gr			1.9	
Siphon 148.2 - 149.4	Qal	1.2			

Table 4-4 (Continued)
Summary of Geologic Conditions
Corridor 1A--Colorado River Aqueduct

Structure/ Milepost	Geologic Map Unit	Soft Ground	Soft Rock	Hard Rock	Geologic Hazards
Tunnel 149.4 - 158.7	gr			9.3	
Tunnel 158.7 - 167.7	pCc			9.0	
Siphon 167.7 - 169.9	Qal	2.2			
Tunnel 169.9 - 174.1	pCc			3.1	
Siphon 174.1 - 174.2	Qal	0.1			
Tunnel 174.2 - 177	pCc			2.8	
Siphon 177 - 178	Qal	1.0			
Tunnel 178 - 181.1	pCc			3.1	
Siphon 181.1 - 181.2	Qal	0.1			
Tunnel 181.2 - 184.1	pCc			2.9	
Siphon 184.1 - 184.5	Qal	0.4			
Tunnel 184.5 - 185.8	pCc			1.3	
Siphon 185.8 - 186.1	Qco		0.3		
Tunnel 186.1 - 187.7	pCc			1.6	Mission Creek/ N. Branch San Andreas MP 186 - 187
Siphon 187.7 - 193	Qal	5.3			

Table 4-4 (Continued)
Summary of Geologic Conditions
Corridor 1A--Colorado River Aqueduct

Structure/ Milepost	Geologic Map Unit	Soft Ground	Soft Rock	Hard Rock	Geologic Hazards
Siphon 193 - 194	Qc	1.0			Banning/S. Branch San Andreas Mp 194
Siphon 194 - 194.5	Qal	0.5			
Tunnel 194.5 - 195.2	Qco		0.7		
Siphon 195.2 - 195.7	Qal	0.5			
Tunnel 195.7 - 196.7	Qco		1.0		
Siphon 196.7 - 203.8	Qal	7.1			
Tunnel 203.8 - 205.4	gr			1.6	
Tunnel 205.4 - 209	grm, ms			3.6	
Tunnel 209 - 214.2	gr			5.2	
Tunnel 214.2 - 216.7	grm, ms			2.5	
Siphon 216.7 - 219.6	Qal	2.9			San Jacinto Fault MP 217.5
Canal 219.6 - 229	Qal	9.4			Casa Loma Fault MP 220.0
Canal 229 - 229.5	Kgr			0.5	
Canal 229.5 - 231.5	Qal	2.0			
Canal 231.5 - 232	Kgr			1.5	

Table 4-4 (Continued)
Summary of Geologic Conditions
Corridor 1A--Colorado River Aqueduct

Structure/ Milepost	Geologic Map Unit	Soft Ground	Soft Rock	Hard Rock	Geologic Hazards
Canal 232 - 237	Qal	5.0			
Canal 237 - 238	ms			1	
Total		145.7	7.1	84.7	

Qal Quaternary age alluvium - soft ground.
Qc Quaternary age nonmarine sediments - soft ground.
Qco Quaternary age older nonmarine sediments - soft rock.
Tc Tertiary age nonmarine sediments - soft rock.
Tv Tertiary age volcanic rocks - hard rock.
gr Undifferentiated granitic rock - hard rock.
grm Undifferentiated granitic and metamorphic rock.
ms Undifferentiated medisedimentary rock - hard rock.
pCc PreCambrian igneous and metamorphic rock - hard rock.

Table 4-5
Summary of Geologic Conditions
For the Parallel Canal Corridor

Segment	Milepost	Geologic Map Unit	Active Fault Crossings	Parallel To
Imperial Dam to Drop 1	0 - 0.9	Qc		AAC
	0.9 - 1.2	Qal		AAC
	1.2 - 1.8	Qc		AAC
	1.8 - 3.2	Qal		AAC
	3.2 - 3.8	mc		AAC
	3.8 - 4.0	Qal		AAC
	4.0 - 4.1	Trb		AAC
	4.1 - 5.0	Qal		AAC
	5.0 - 5.4	Qc		AAC
	5.4 - 5.8	Qal		AAC
	5.8 - 6.1	Qc		AAC
	6.1 - 7.3	Qal		AAC
	7.3 - 7.6	Qc		AAC
	7.6 - 20.8	Qal / Qc		AAC
	20.8 - 21.1	mc		AAC
	21.1 - 22.7	Qc		AAC
	22.7 - 24.1	Qal		AAC
	24.1 - 34.1	Qs	Sand Hills (33.7)	AAC
	34.1 - 35.0	Qal		AAC
Drop 1 to Thistle Lateral	0 - 7.6	Qal		AAC
	7.6 - 9.5	Qs / Qal		AAC
	9.5 - 18.9	Qal		AAC
	18.9 - 44.3	Ql	Imperial (25.2)	AAC
	44.3 - 69.8	Ql	Superstition Mtn. (67.0)	Westside Main Canal
	69.8 - 75.9	Ql	Superstition Hills (69.8)	Thistle Canal

Legend:
Ql - Lake bed deposits
Qal -Alluvium
Qs - Sand dunes
Qc - Older alluvium
Trb -Sedimentary breccia
mc - Chuckawalla Complex

Mesa area The alluvium consists of unconsolidated silt, sand, clay and gravel Sand dunes (Qs) are found along the corridor in the Sand Hills and again briefly approximately 8 miles east of Drop 1 Older alluvium (Qc) deposits consisting of poorly cemented dissected alluvial fans are crossed by the corridor near Imperial Dam and along the broad alluvial fans emanating from the Cargo Muchacho Mountains and Pilot Knob The older alluvium consists mainly of poorly sorted silt, sand, and gravel.

The sedimentary breccia (Trb), which is crossed approximately 4 miles southwest of Imperial Dam, consists of a poorly to moderately well cemented breccia composed of metavolcanic and metasedimentary rocks in a silt and sand matrix The last formation and the only hard rock unit is the Chuckawalla Complex This unit is crossed by the corridor about 3 miles southwest of Imperial Dam and again south of Pilot Knob. The Chuckawalla Complex is a Precambrian rock consisting of diorite gneiss and foliated granitic rocks.

Due to seepage from the existing unlined AAC, a high groundwater table is expected along a the majority of a new parallel canal This high groundwater table is evident by the wetland areas and marshes which have formed along portions of the canal.

Geologic hazards along a parallel canal include fault rupture, ground shaking, liquefaction, and to a lesser extent scour and erosion Landslides are not considered to be a problem due to the low relief terrain along the corridor.

As shown on Table 4-5, the corridor crosses several active faults including the Imperial fault which cross the AAC, and the Superstition Mountain and Superstition Hills faults which cross the Westside Main and Thistle Canals. The most active fault in the project area is the Imperial fault which crosses the corridor near milepost 25 This fault has experienced two surface rupturing events with an M7.0 event in 1940, and an M6.5 event in 1979 The 1940 event resulted in surface rupture of up to 15 feet near Calexico and widespread damage to canal systems. Between 1900 and 1940, four events occurred in the area with magnitudes estimated at between 5.5 and 6.3. Some or all of these events may have occurred on the Imperial fault Recent ground rupture has also occurred on the Superstition Hills fault during an M5.6 event in 1951 and again in 1987 during an M6.6 earthquake.

Earthquake activity in the Imperial Valley is higher than anywhere else in California. This activity has been characterized by clusters of earthquake swarms on the Brawley fault zone interspersed with magnitude 5 to 7 earthquakes on the Imperial fault. Other nearby seismic sources include the Superstition Hills and Superstition Mountain faults (components of the San Jacinto fault zone), the Laguna Salada and Cerro Prieto faults in Mexico, and the San Andreas fault.

Given this high rate of seismicity and a geologic setting characterized by young sediments and a shallow water table, the Imperial Valley has a high potential for liquefaction and secondary ground failures including slumps and lateral spreads, and ground settlement. As a result of these conditions, extensive damage to canals was experienced during the 1940 and the 1979 events on the Imperial fault The AAC was extensively damaged in 1979 along an 8 mile section adjacent to the Imperial fault. Damage was more severe in 1940 and included greater damage to gates and drops. In general the severe canal damage was limited to areas within about 6 miles of the surface rupture.

Scour and erosion is a potential hazard in the area between Imperial Dam and Pilot Knob where dry washes cross the corridor The larger of washes include Imperial Wash, Picacho Wash, and Araz Wash. In addition, the New and Alamo Rivers present a possible erosion and flooding hazard. The Sand Hills are also subject to erosion due to heavy rainfall and wind shifting the dunes.